

# Framing the Issues on Spaceship Earth

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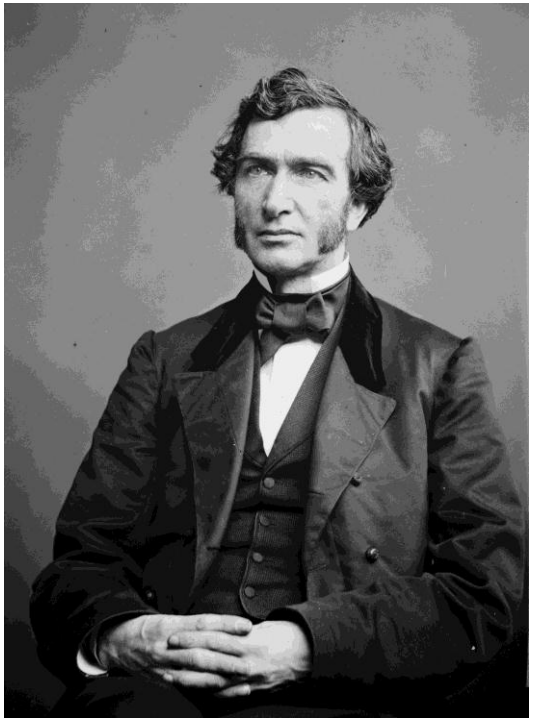
**Consultative Group for International Agricultural Research**

# Then



**1862**

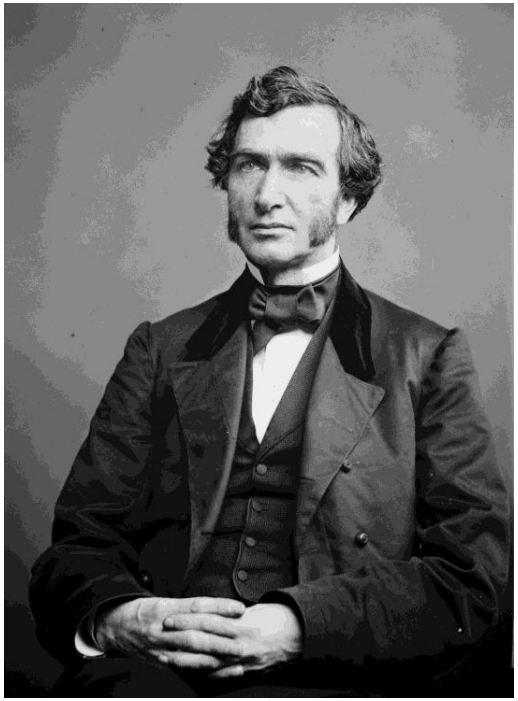
USA population:

32 million

Global population

1.2 billion

# Then and Now



**1862**

USA population:

32 million

Global population

1.2 billion

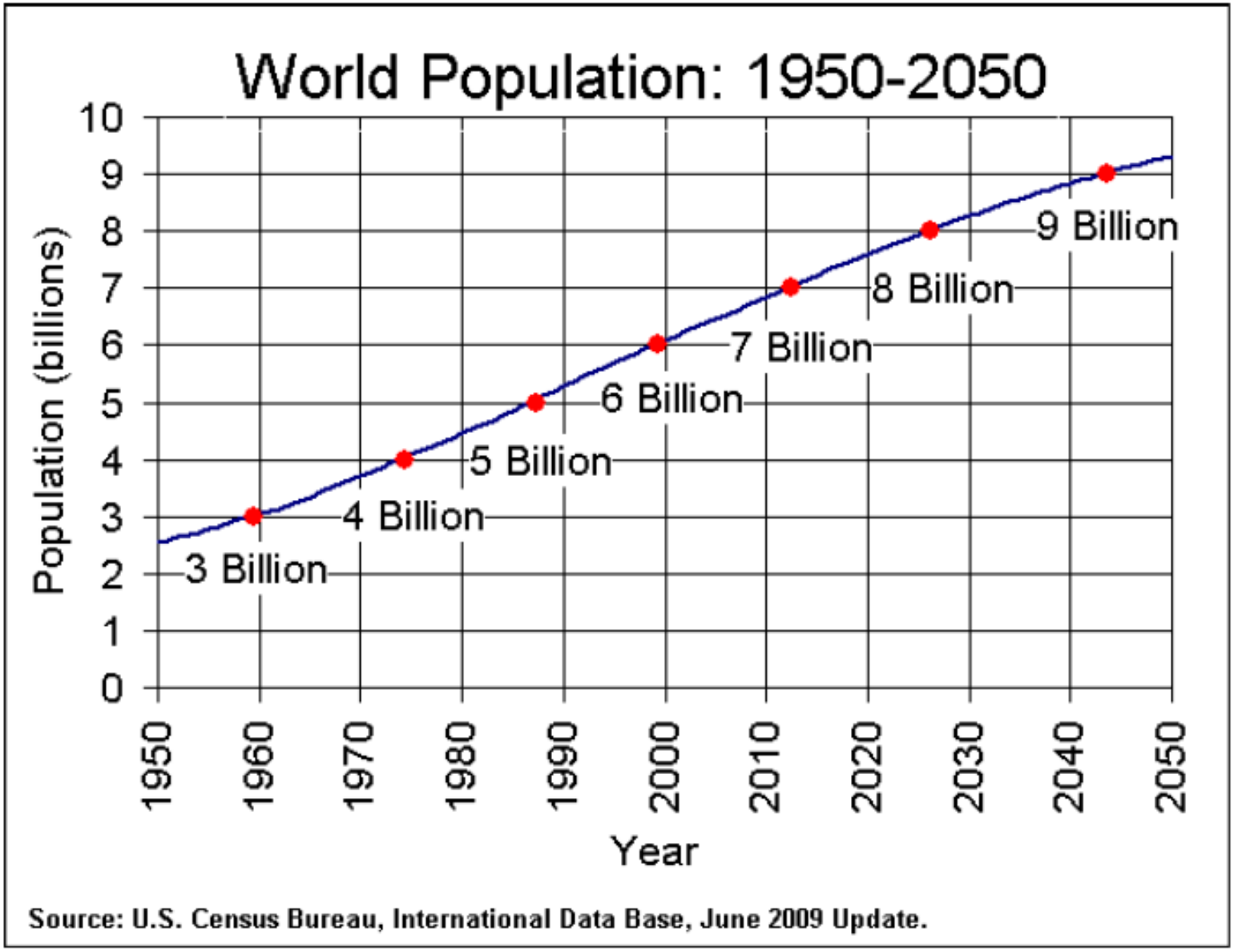
**2010**

USA population:

309 million

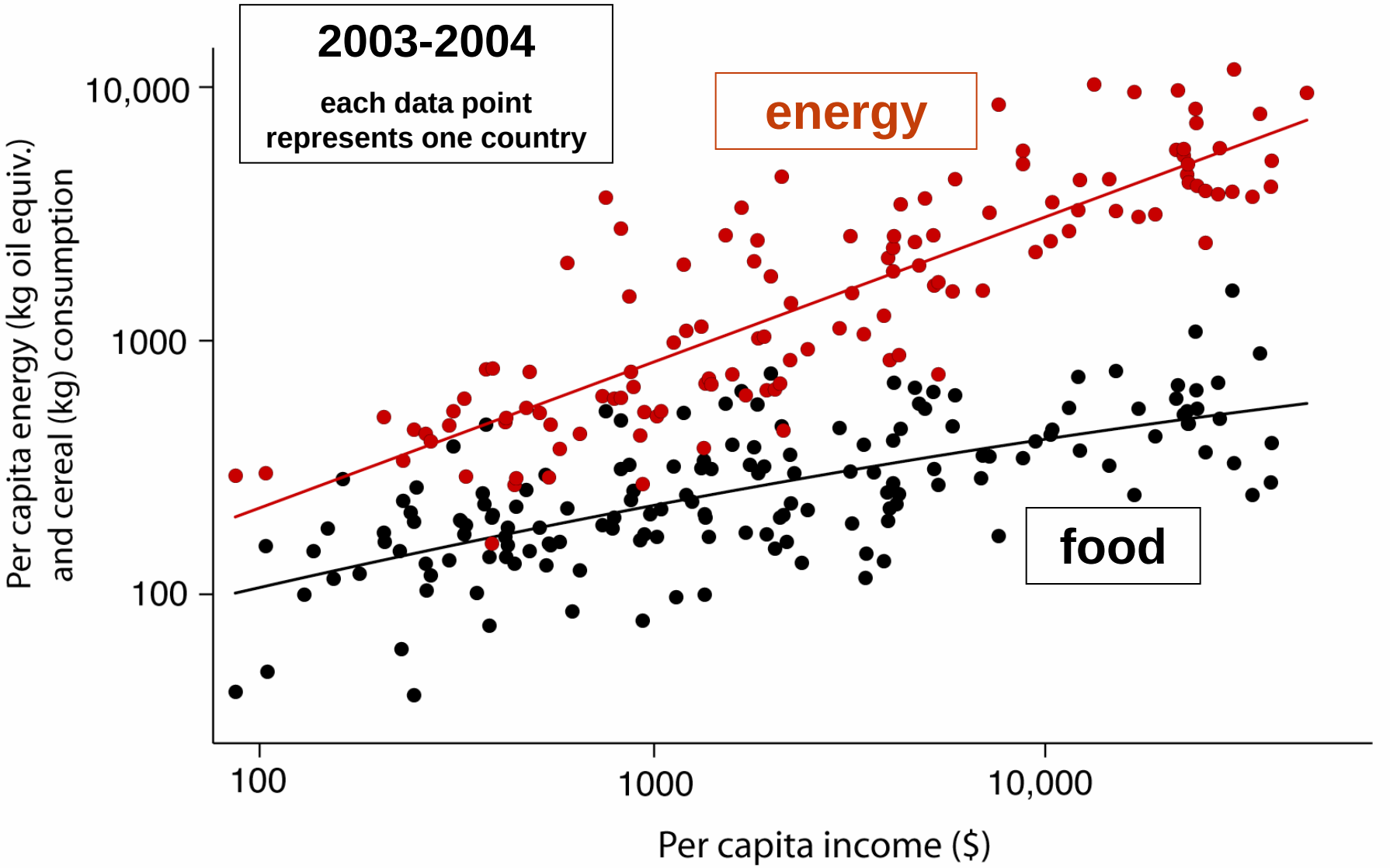
Global population

6.9 billion


World Population: 1950-2050
Population (billions)
0
1
2
3
4
5
6
7
8
9
10
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Year
3 Billion
4 Billion
5 Billion
6 Billion
7 Billion
8 Billion
9 Billion
Source: U.S. Census Bureau, International Data Base, June 2009 Update.

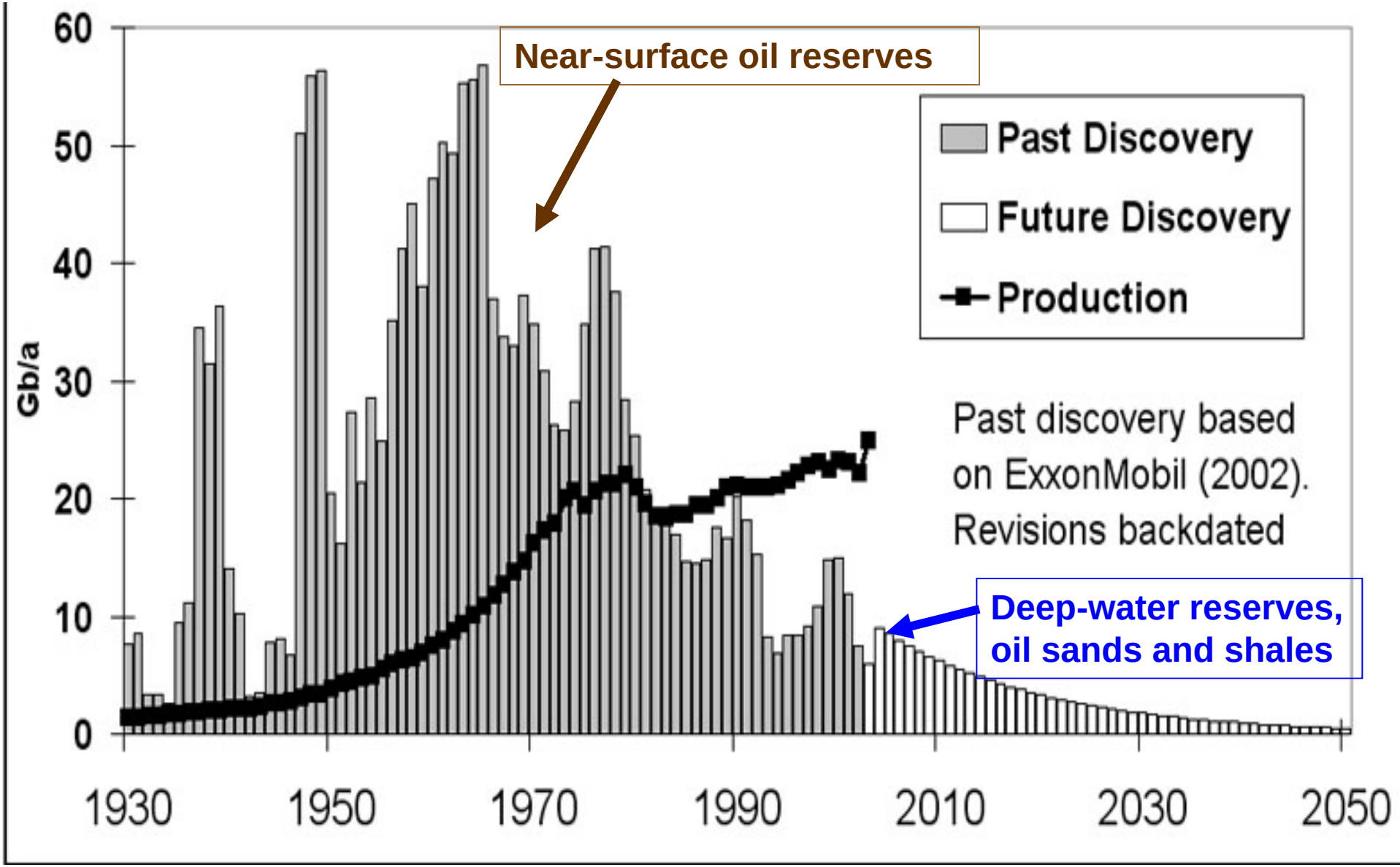
We live on a much smaller, resource limited planet than the one Justin Morrill Smith lived on…..

# Energy or Cereal Consumption versus Income by Country



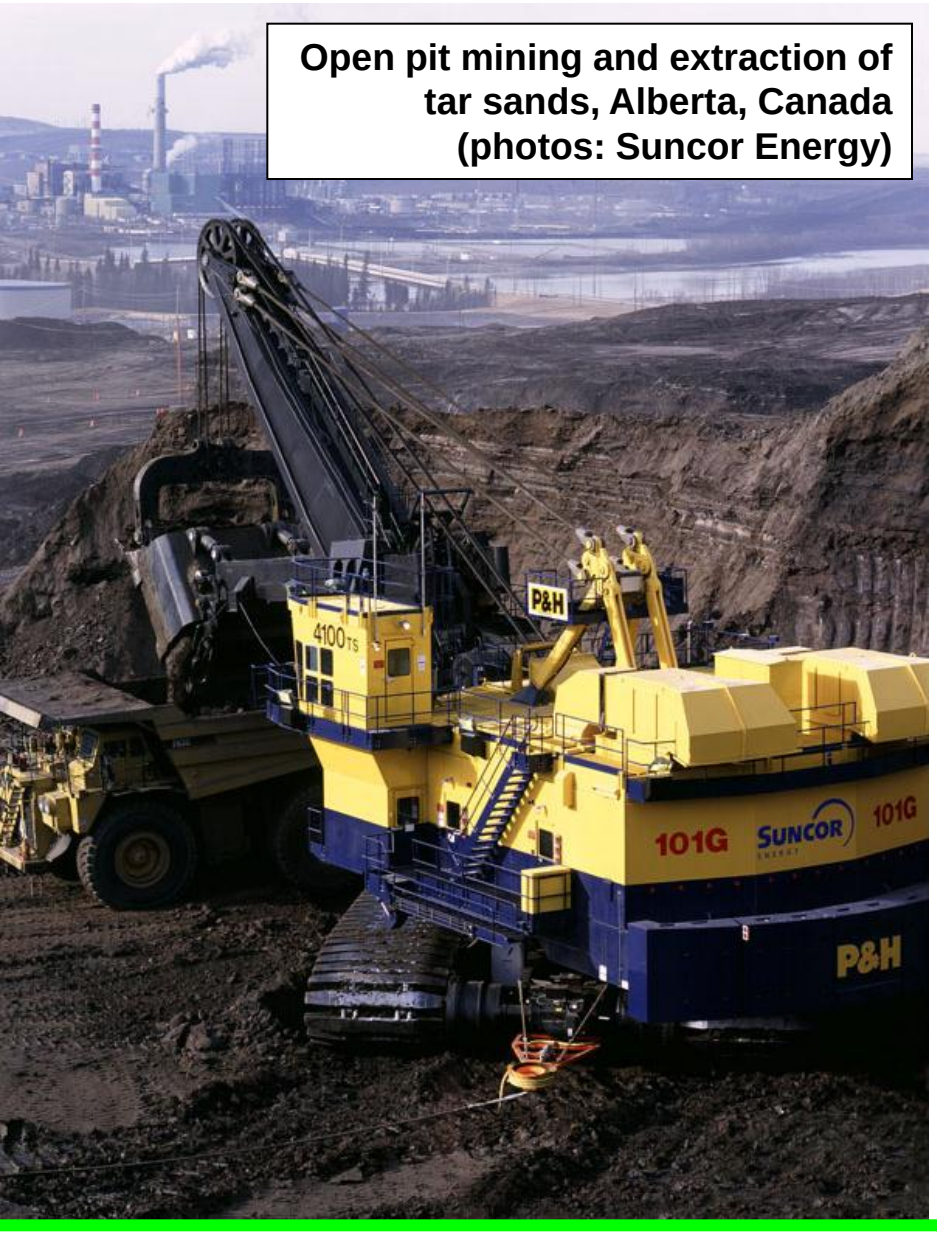

**Naylor et al., 2007. *Environment* 40: 30-43.** Energy and income data from World Bank development indicators; cereal consumption data from FAOSTAT.

# Oil Production vs Oil Discovery



# Biofuels compared to what in a world with changing climate?


**Deep water petroleum? Oil sands? "Frac" natural gas? Coal? Nuclear Power?**




Open pit mining and extraction of tar sands, Alberta, Canada (photos: Suncor Energy)

**What is your choice for a transition energy source to renewable, carbon-free energy?**

San Onofre nuclear plant, California

# Food Security as a Metaphor

- **Complex goal tightly linked to health, poverty, equity, political stability, quality of life, environmental quality and natural resource conservation**

# What is Food Security?

- **When all people at all times have physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life (USAID, FAO, WHO)**
  - **Availability (sufficient quantity and quality)**
  - **Access (affordability, functioning markets)**
  - **Safety and sanitation**
  - **Stability (avoid "feast and famine" cycles)**

# Food Security as a Metaphor

- **Complex goal tightly linked to health, poverty, equity, political stability, quality of life, environmental quality and natural resource conservation**
- **Requires "all of science" to adequately address it**
- **While producing enough food is a key component, it is "necessary but not sufficient" to achieve food security at local to global levels**
- **Time-bound challenge -- solutions need to be forthcoming within next 10-20 years, assuming time required for extension and adoption, requires rigorous prioritization**

# “All of Science”

- Interdisciplinary, systems-oriented, integrative, basic and applied
- Biophysical, medical, and social sciences
- Information technology, computer science
- Education, capacity building, technology transfer
- Improved capacity for research prioritization at global, national, and university levels

# Brave New World Since 2007

- **Rapid, sustained economic growth in the most populous developing countries**
- **Rapid rise in petroleum prices**
- **Convergence of energy and agriculture**
- **Falling supply relative to demand for staple food prices**

**Urban-industrial expansion onto prime farmland at the periphery of Kunming (+6 million), the capital of Yunnan Province, China,**

**Photo: K.G. Cassman**

# Clearing virgin rain forest in Brazil: powerful +feedback to GHG emissions

Slash and burn cropping systems on hillsides in Sumatra, Indonesia

# Brave New World Since 2007

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- Falling supply relative to demand for staple food prices
- **Increased poverty and malnutrition**

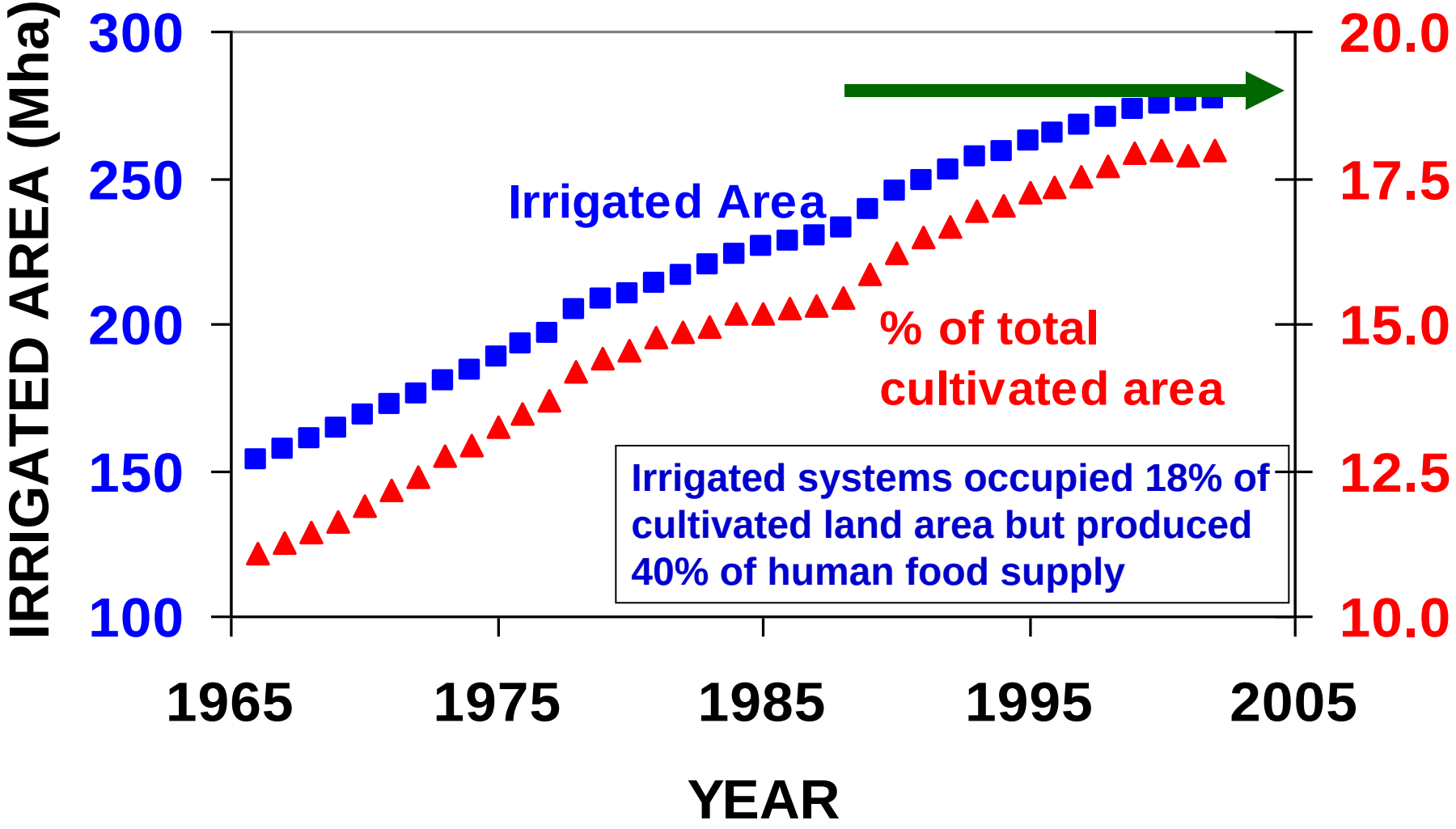
**Food insecurity: unsustainable crop production on marginal land by poor farm families without other options**

Photo: K.G. Cassman

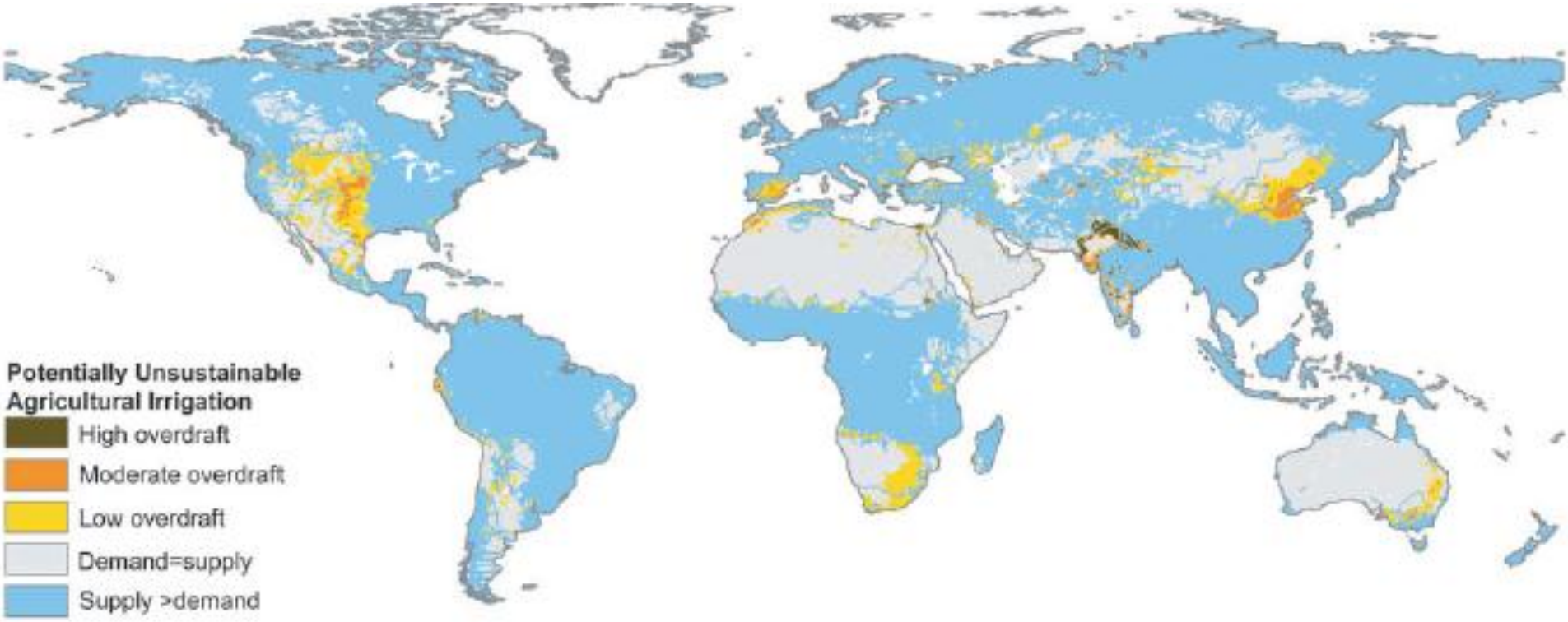
# Brave New World Since 2007

- Rapid, sustained economic growth in most populous developing countries
- Rapid rise in petroleum princes
- Convergence of energy and agriculture
- Smaller supply, relative to demand, of staple food crops; steep rise in the price of these foods
- Increasing poverty and malnutrition
- **Limited supplies of good quality arable land and accessible fresh water**
- **Stagnating yields in some of the most productive cropping systems**

# Global Irrigated Area and as a % of Total Cultivated Land Area, 1966-2004



# Decreasing water supply in all major irrigated areas

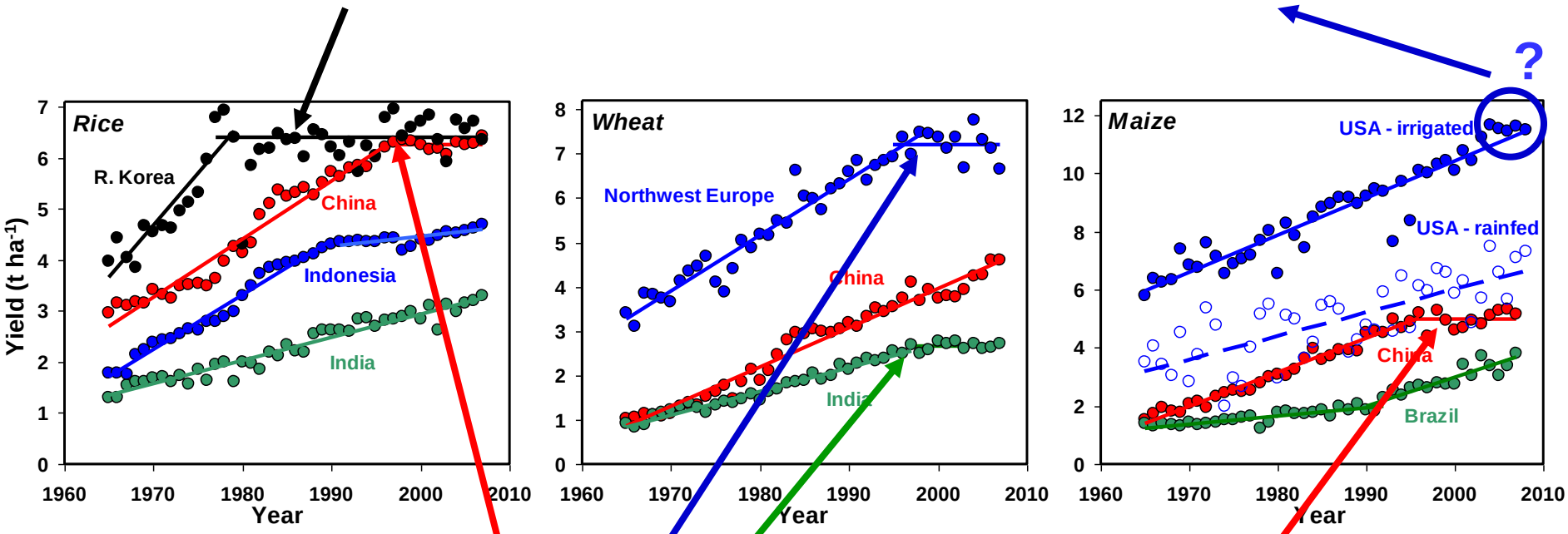



**In an increasingly urban world, irrigated agriculture is more important than ever to provide "ballast" to global food supply**

**Also a concern are yield plateaus for several major crops. What are the causes? Korea and China for rice, wheat in northwest Europe and India, maize in China, and…….perhaps also for irrigated maize in the USA??**

Cassman, 1999. PNAS, 96: 5952-5959

Grassini et al., 2011. FCR 120:142-152




Cassman et al., 2003, ARER 28: 315-358

Cassman et al., 2010, Handbook of Climate Change

Crop Sci. 50:1882–1890 (2010)

## Genetic Improvement in Winter Wheat Yields in the Great Plains of North America, 1959–2008

Robert A. Graybosch* and C. James Peterson

### Abstract

……Linear regressions of relative grain yields vs. year over the time period 1984 to 2008, however, showed no statistically significant trend in the SRPN. For the same time period in the NRPN, a statistically significant positive slope of 0.83 was observed, though the coefficient of determination (*R*2) was only 0.28. …….. and further improvement in the genetic potential for grain yield awaits some new technological or biological advance.

Field Crops Research 119 (2010) 201–212

## Why are wheat yields stagnating in Europe? A comprehensive data analysis for France

Nadine Brissona,∗, Philippe Gateb, David Gouacheb, Gilles Charmetc, Francois-Xavier Ouryc, Frédéric Huarda

### Abstract

The last two decades are witnessing a decline in the growth trend of cereal yields in many European countries. The present study analyses yield trends in France using various sources of data: national and regional statistics, scattered trials, results of agroclimatic models using climatic data.

# Brave New World Since 2007

- Rapid, sustained economic growth in most populous developing countries
- Rapid rise in petroleum princes
- Convergence of energy and agriculture
- Smaller supply, relative to demand, of staple food crops; steep rise in the price of these foods
- Increasing poverty and malnutrition
- Limited supplies of good quality arable land and accessible fresh water
- Stagnating yields in some of the most productive cropping systems
- THESE ARE LIKELY TO BE LONG-TERM TRENDS

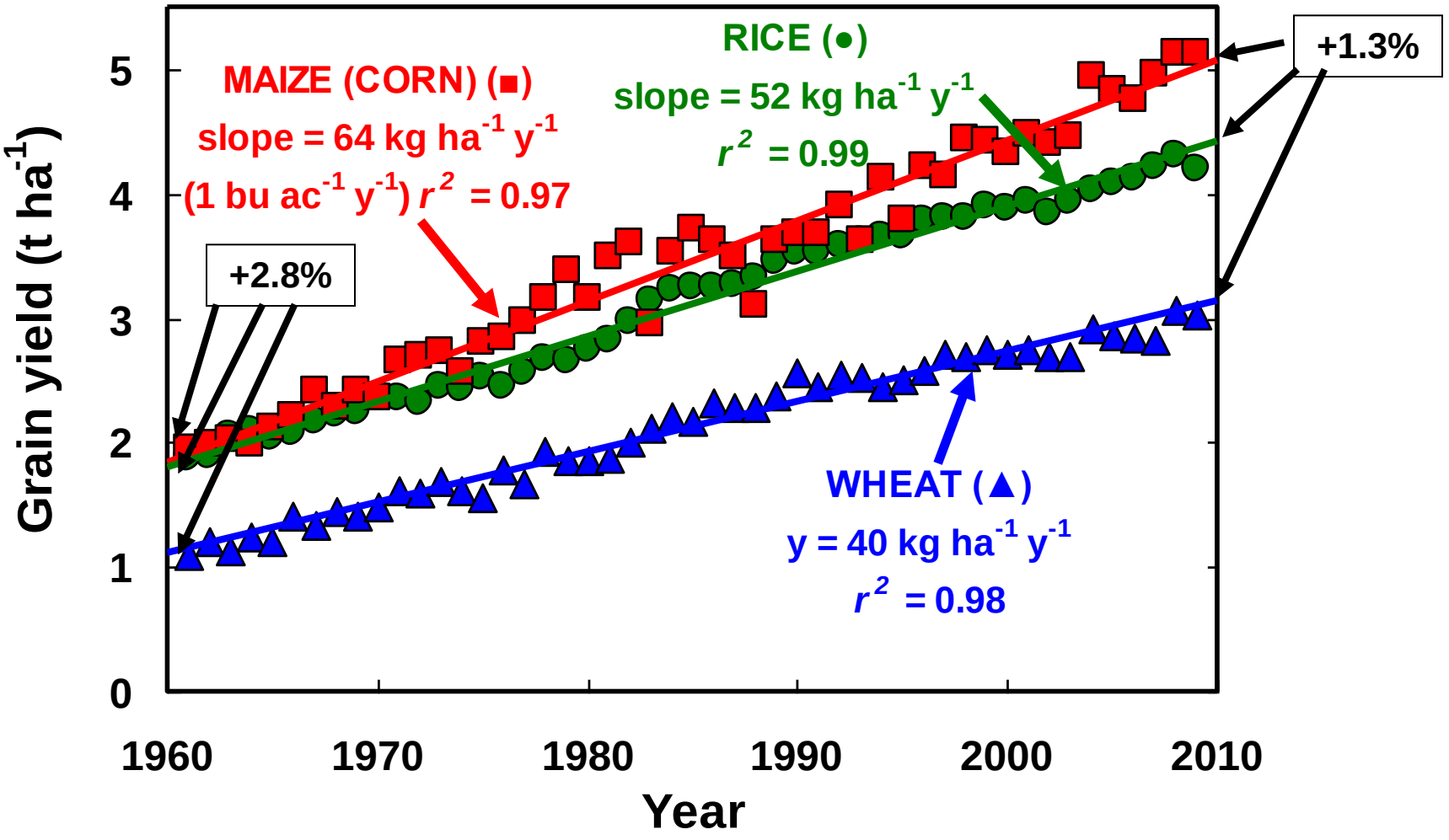
# Mega Trends in Food Supply-Demand Balance

- Are current trajectories for yield advance sufficient to meet projected demand of a world with 9+ billion people who are wealthier, on average, than today, on existing arable land base?
- If yes, let's go home and celebrate!
- If not, ……

# A Key Component of Food Security

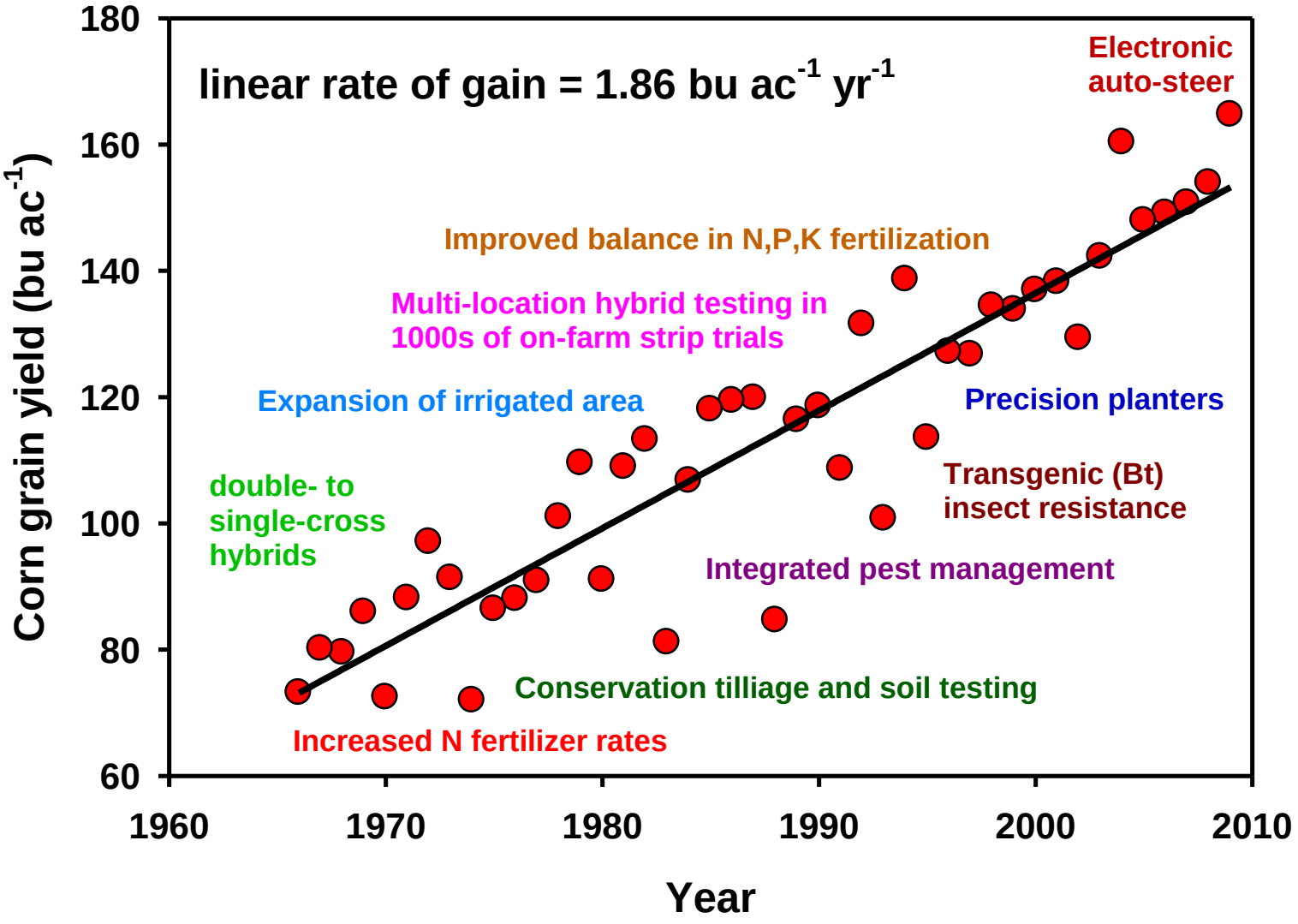
- **Adequate supply of staple food crops (calories and protein: cereal, oilseed, starch crops): NECESSARY BUT NOT SUFFICIENT**
  - **Directly affects affordability of staple foods and incomes, especially rural and urban poor**
  - ***Indirectly* affects affordability of nutritionally adequate diets**
  - ***Indirectly* affects stability of food supply and pressure to expand crop production area**
- **Retirement planning analogy**

# Global Cereal Yield Trends, 1966-2009




**THESE RATES OF INCREASE ARE NOT FAST ENOUGH TO MEET EXPECTED DEMAND ON EXISTING FARM LAND!** source: FAOSTAT

# USA Corn Yield Trends, 1966-2009
# (and supporting science and technologies)




Modified from: Cassman et al. 2006. Convergence of energy and Agriculture. Council on Agriculture, Sci. Tech. Commentary QTA 2006-3. Ames, Iowa

# Assuming a goal of no net expansion of current crop production area……

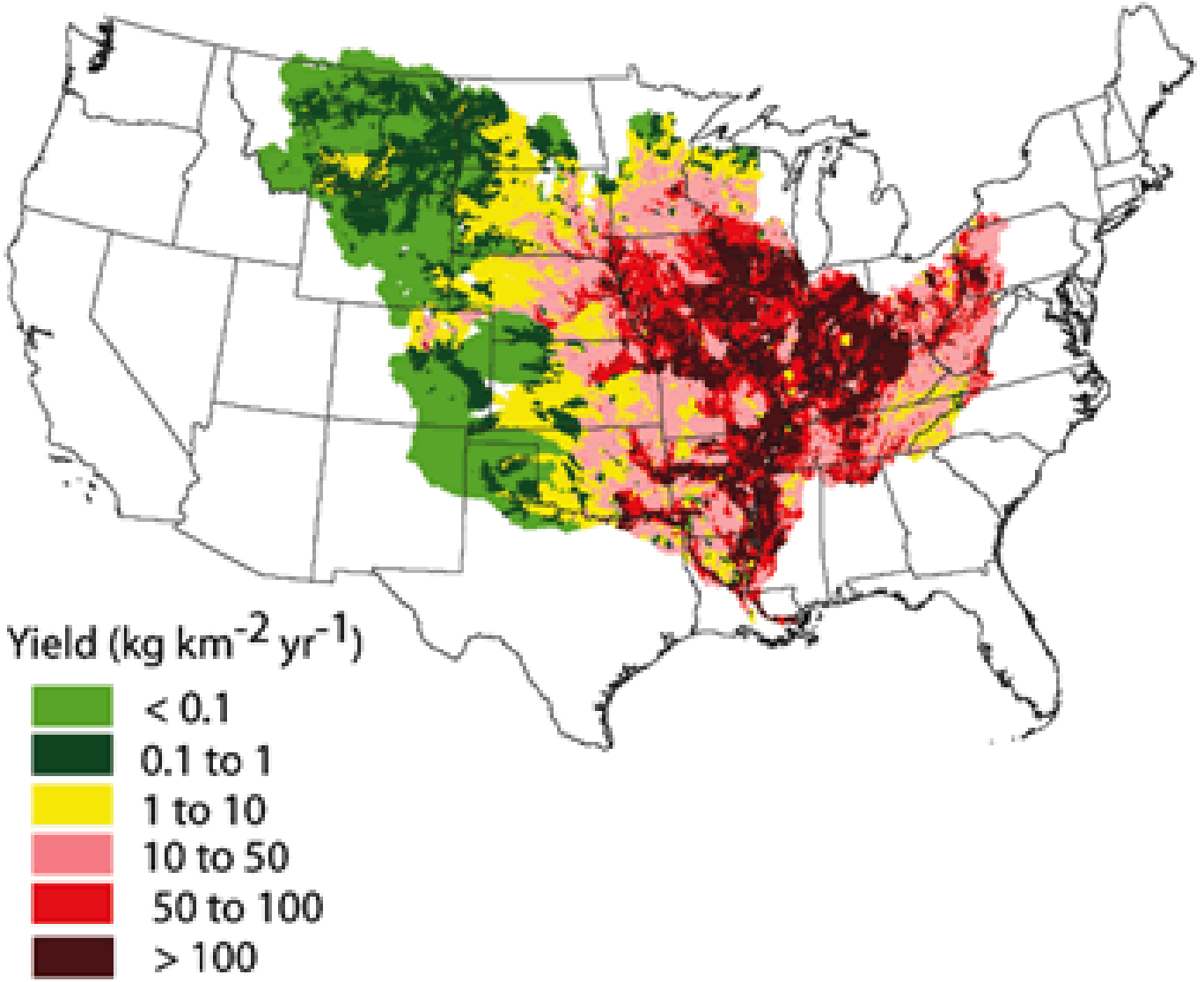
- A ~60% increase in cereal* yields needed by 2050 (39 yr) = 1.54% $yr^{-1}$ of current average yield
- Business as usual will not meet 2050 global demand for food, feed, fuel in without large expansion of crop area
- How much help from less meat and less post-harvest losses and food waste?

*Cereals for food, feed, fuel, bio-industrials

# The Challenge is Clear

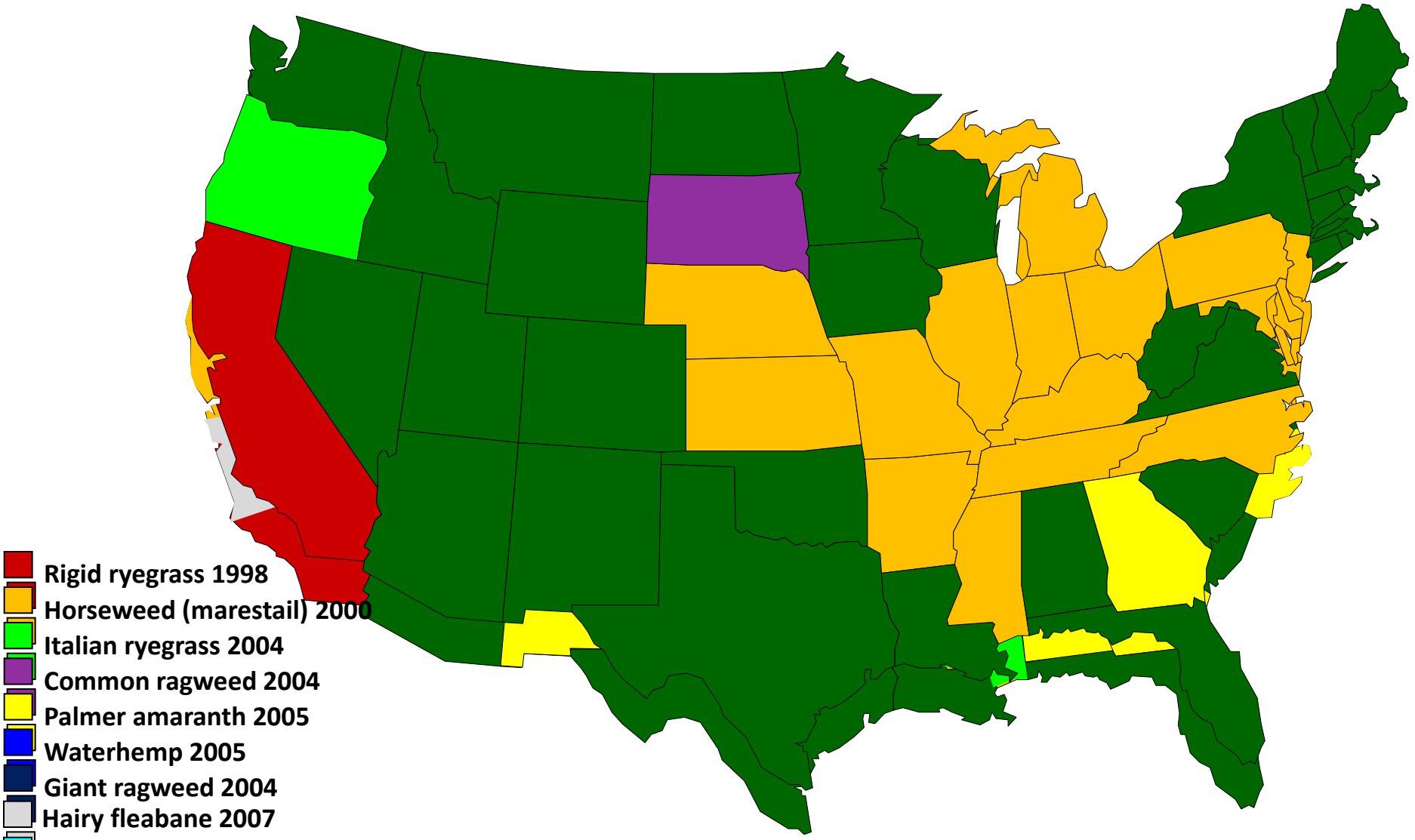
- **Increase food supply +70% (cereals + 60%) on existing crop and pasture land**
- **Substantially decrease environmental footprint of agriculture**
  - **Protect water quality and conserve water for non-agriculture uses**
  - **Maintain or improve soil quality**
  - **Reduce greenhouse gas emissions**
  - **Protect wildlife and biodiversity**
- **Called "sustainable intensification"**

# Also needed: large reduction in nutrient losses, primarily N and P, from agriculture to surface and ground water resources



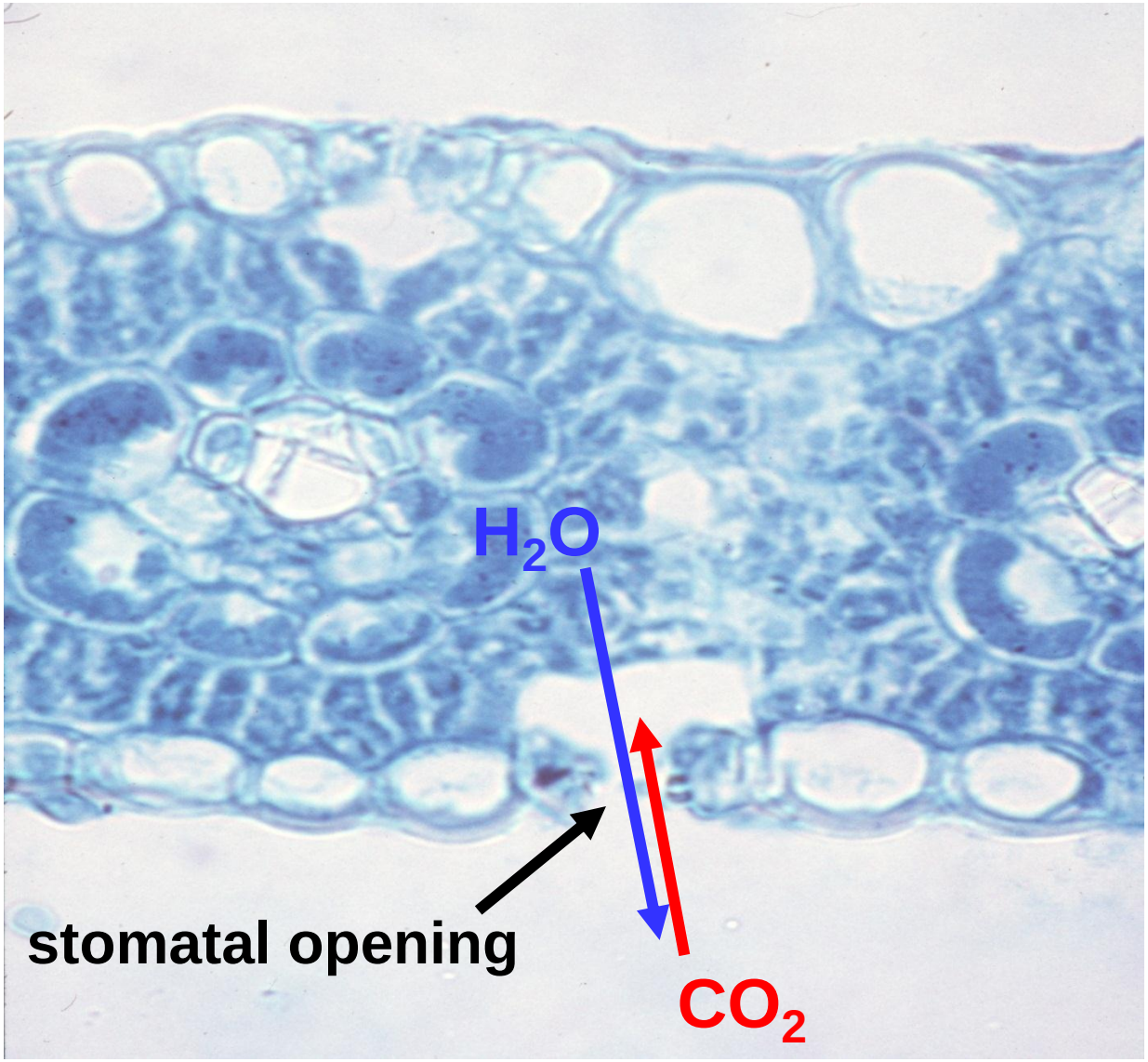

Sources of phosphorus losses to Gulf of Mexico: Alexander et al, Environ. Sci. Tech, 2008.

# We mujst deal with the “Red Queen” tyranny, e.g. glyphosate-resistant weeds



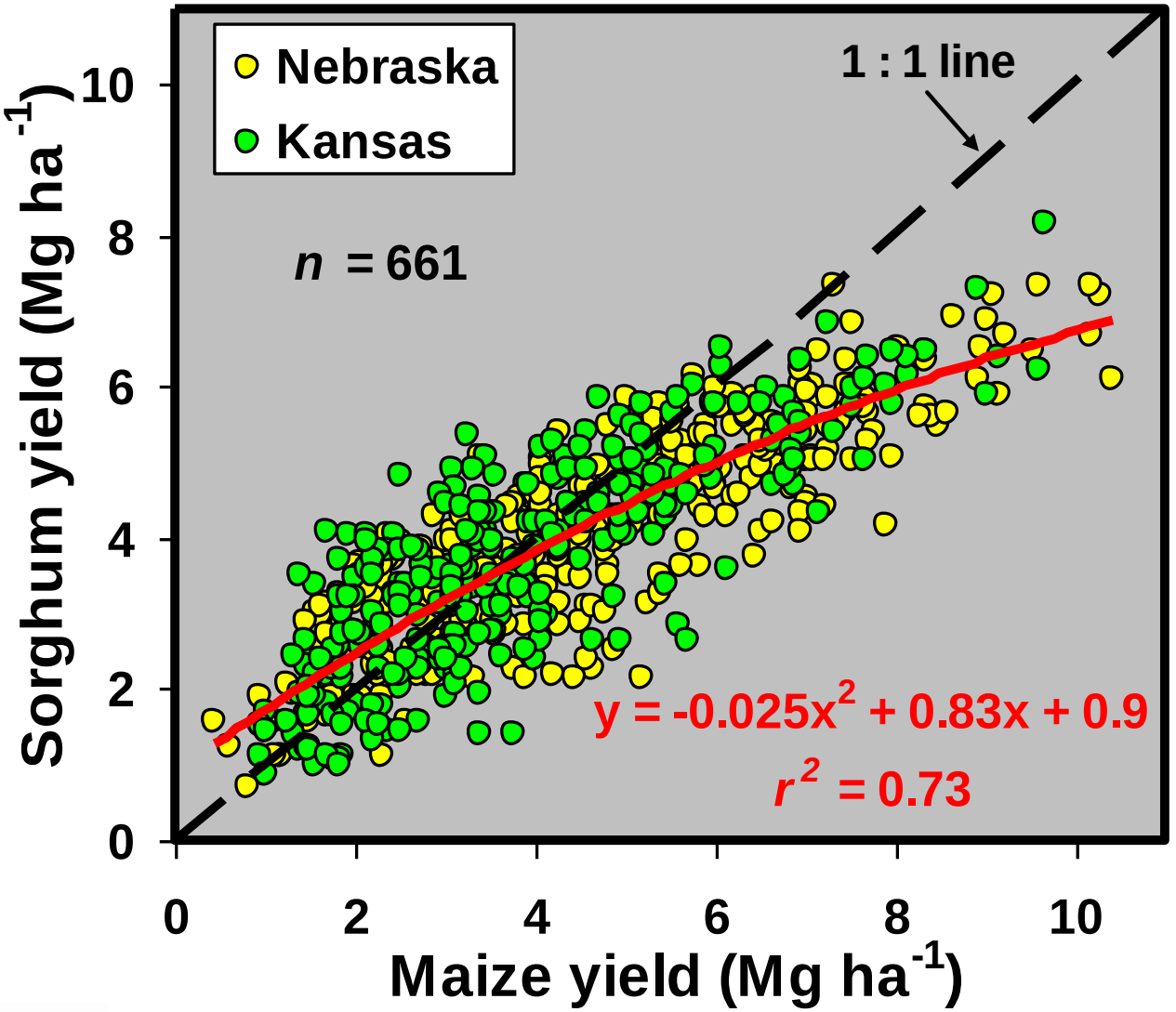

Source: Survey of Herbicide Resistant weeds, http://www.weedscience.org/In.asp

# We need break thoughs to improve water productivity of our major food crops (trade-off free)




Leaf cross-section showing the tight biophysical linkage between photosynthesis, which requires movement of carbon dioxide into the leaf from the atmosphere, and water loss from mesophyll cell surfaces within the leaf.

# Trade offs in yield at difference levels of water suppy: the case of sorghum vs maize under rainfed conditions in NE and KS counties where both crops are grown, 2000-2009†




†Grassini and Cassman, unpublished data. Source: USDA-NASS

# Need for both conventional breeding and biotechnology (proper balance?)

Courtesy of Richard Richards, CSIRO, Australia.

# Break throughs in sustainable intensification

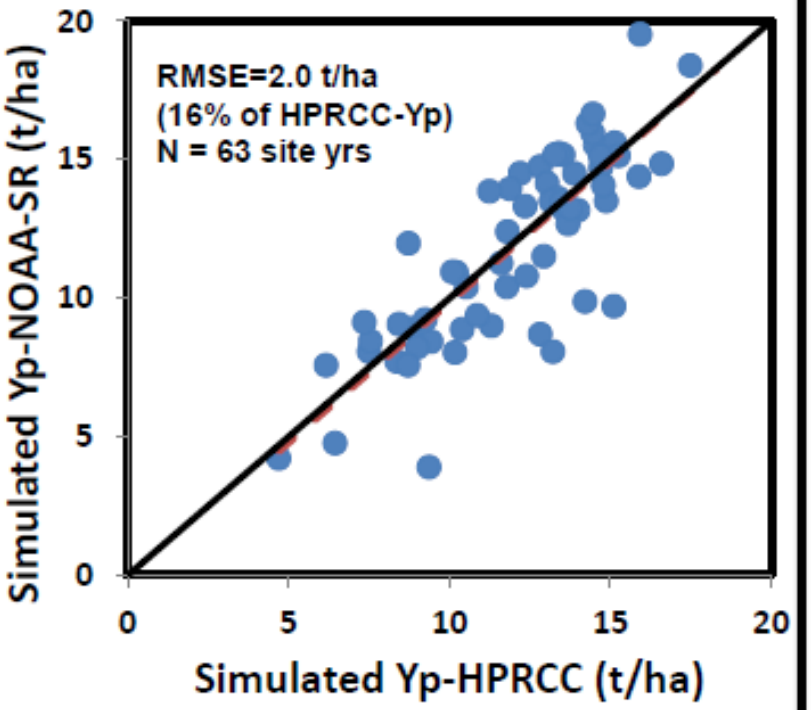
- **Support vibrant rural communities**
- **Eliminate erosion and nutrient losses**
- **Improve soil quality**
- **“Climate-smart”, resilient, opportunistic**
- **Protect natural environmental services, including biodiversity and wildlife**
- **Weather forecasting, simulation models, decision-support tools, remote sensing, real-time in-season management, etc….**

# Concern about sources of weather data used to estimate impact of climate change on crop yields

| | | |
|---|---|---|
| HPRCC | high quality, ground weather station data, rigorous quality control; daily | - |
| NOAA-SR | Global network of ground weather stations, quality controlled, coupled with NASA solar radiation data; daily | **-Lobell et al., '11-Nature Climate Change** |
| NCEP/DOE-reanalysis | "Assimilation" of ground and satellite data; daily; global grid (roughly 250 $km^2$ grids)<br>*Assimilation is analysis, interpolation and forecasting resulting in a simulation of gridded data | **-Nemani et al., '03-Science;**<br>**-Donner and Kucharik, '03-Global Biogeochemical Cycles**<br>**-Lobell et al., '03-Science** |
| CRU | Interpolated data derived from ground weather stations; monthly; global grid (roughly 50 $km^2$ grids), solar radiation derived from temperature and dew point data.<br><br>Sometimes converted to daily weather data using various methods | **-Fischer et al., '02-IAASA AEZ analysis;**<br>**-Foley et al., '05-IBIS Model;**<br>**-Lobell and Field, '07, Environ. Rsrch. Letters**<br>**-Lobell et al., '11-Science**<br>**-Licker et al., 2010-Global Ecology and Biogeography**<br>**-Reidsma et al., 2010-European J. of Agron.**<br>**-Used as input for GCM in IPCC-4** |
| NASA | Derived from observed satellite data; daily with global grid (roughly 100 $km^2$ grids): Temp, rainfall, solar radiation | **--HarvestChoice Project (harvestchoice.org)** |

Source: Justin van Wart, PhD thesis, 2011, University of Nebrasaka, Lincoln

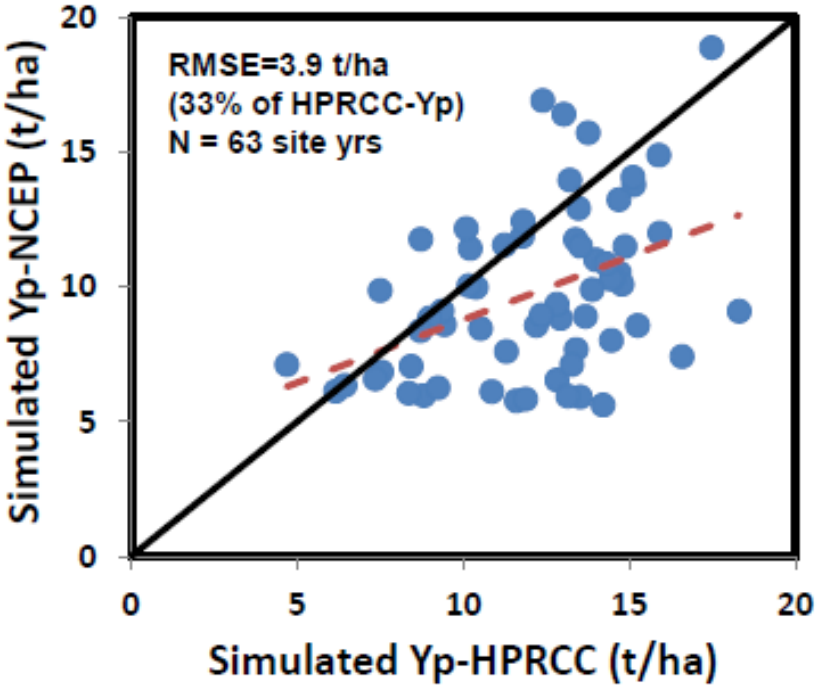
**Simulated Rainfed Maize Yp: NOAA-SR vs HPRCC weather data (1990-2008)**




Avg-HPRCC-YP across all site years: 12.1 t/ha

Avg NOAA-SR-Yp across all site years: 12.0 t/ha

**Simulated Rainfed Maize Yp: NCEP vs HPRCCC weather data (1990-2008)**

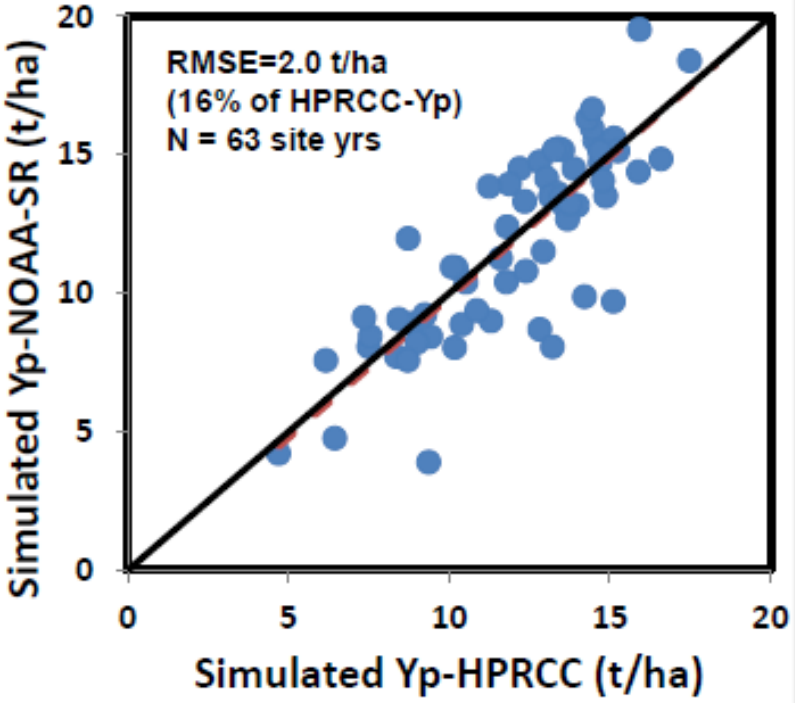



Avg-HPRCC-YP across all site years: 12.1 t/ha

Avg NCEP-Yp across all site years: 9.8 t/ha

Source: Justin van Wart, PhD thesis, 2011, University of Nebrasaka, Lincoln

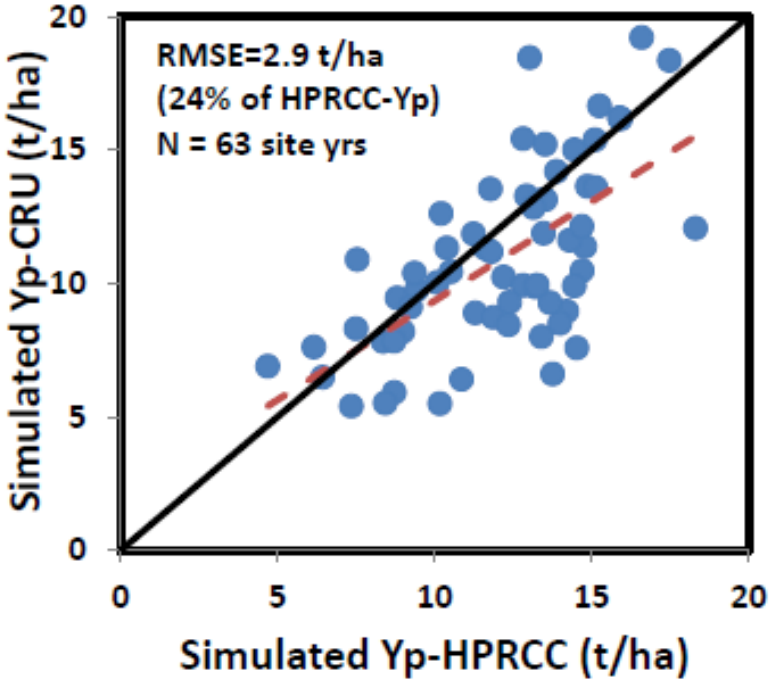
## Simulated Rainfed Maize Yp: NOAA-SR vs HPRCC weather data (1990-2008)




Avg-HPRCC-YP across all site years: 12.1 t/ha

Avg NOAA-SR-Yp across all site years: 12.0 t/ha

## Simulated Rainfed Maize Yp: CRU vs HPRCCC weather data (1990-2008)

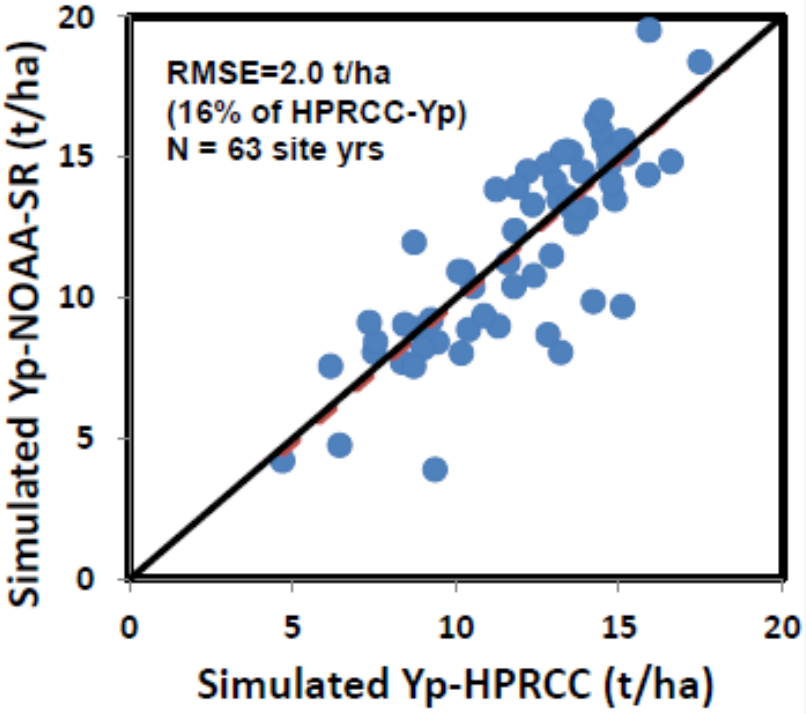



Avg-HPRCC-YP across all site years: 12.1 t/ha

Avg CRU-Yp across all site years: 10.9 t/ha

Source: Justin van Wart, PhD thesis, 2011, University of Nebrasaka, Lincoln

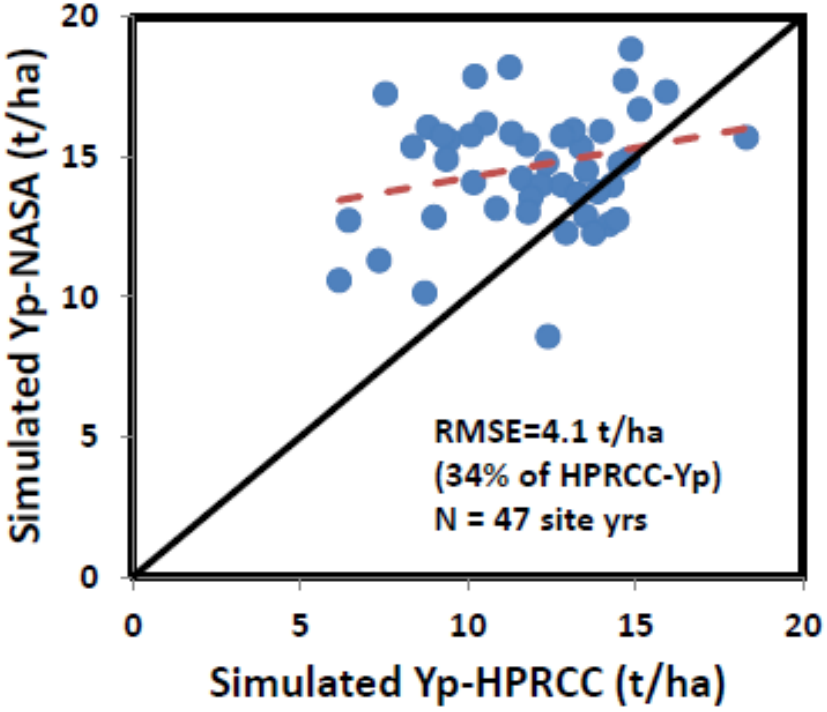
## Simulated Rainfed Maize Yp: NOAA-SR vs HPRCC weather data (1990-2008)




Avg-HPRCC-YP across all site years: 12.1 t/ha

Avg NOAA-SR-Yp across all site years: 12.0 t/ha

## Simulated Rainfed Maize Yp: NASA vs HPRCCC weather data (1997-2008)




Avg-HPRCC-YP across all site years: 11.9t/ha

Avg NASA-Yp across all site years: 14.7 t/ha

# Questions to support effective research prioritization to address food security

- What do we know, what do we need to know, and when do we need the answers? (time bound, 10-20 yrs)
- What educational, institutional, and human resources will be required?
- How much funding is required to support the needed research, education, and capacity building?
- Where do we find the funding resources?
- What are comparative advantages of public- and private sectors, and how do we leverage synergies?
- What is the role of our land-grant universities?

# "All of Government" (AoG)

- If we do a good job and bet on winners, AoG is a fantastic strategy
- If we do a poor job and bet mostly on losers, big trouble ahead…..
- Our track record of betting on winners during past 20 yrs is tepid
  - 5 yrs ago global models were predicting real prices of staple foods would continue to decline to 2030
  - Transgenic crops: Bt & RR, what else since 1990?
  - Less than 50% of applied N fertilizer is taken up by our major crops
  - How much longer for 2nd generation biofuels?

# Food Surplus or Food Scarcity? The answer affects research prioritization

- From 1970 to 2007 more than enough food was produced to meet global demand and keep food prices low
  - It did not matter if policy makers in gov't agencies or administrators of land-grant universities prioritized research well to focus on winners—there was more than enough food for all…..
- From now on, it will be very difficult to keep food production ahead of supply; high food prices (and price spikes) are likely unless….
  - The decisions we make today on research prioritization have an impact on future food security, nutrition, and environmental quality for +9 billon people in 2050